INTEREST OF AN ISOTONIC AMPHOTERIC SOLUTION IN THE EARLY TREATMENT OF CHEMICAL BASIC CORNEO CONJUNTIVAL BURNS : Experimental and histological study

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SUMMARY

The treatment of conjonctivo corneal burns with water and isotonic solutions, buffered or not buffered shows the superiority of the buffered isotonic solutions (amphoteric solutions) above the other rinsing methods from the intra and extra ocular pH point of view, as well as from the endothelial cells point of view.

I- INTRODUCTION

The lesions provoked by ocular splashes due to strong bases often have serious to dramatic consequences.
These accidents frequently happen in the industry where large quantity of soda or ammonia are used.
In this field, we tried to build up the most efficient methods for the immediate treatment of ocular burns which would happen despite the obligation of wearing protective glasses.
Two systems are used now : the Eyewash system based on the use of a bottle linked to an eyecup delivering a solution isotonic to the tears, buffered or not, or the rinsing with water from tap or special showers adapted to the rinsing of the face or the eyes.
In France, we generally recommend the simple rinsing with tap water, despite the results sometimes disappointing of this method, and despite some foreign works that showed the interest of the rinsing with isotonic or buffered solutions.
That is the reason why we started this study, in order to check the validity of this treatment.

II – REACTIONS OF THE EYE IN CONTACT WITH BASES

The cornea, which is the main subject of this study, acts as a semi permeable membrane in osmotic balance between the intra ocular liquid and the tears. The presence of foreign molecules induces an imbalance creating a flow of substance which tends to re establish the osmotic balance.

We then obtain a flow of ionic and proteinic constituents from the hypertonic centre to the hypotonic centre, and a flow of solvent and constituents not included in the hypertonic solution in the opposite direction. In case of burns, the phenomenon of osmotic migration are increased by the importance of the skin and tissue necrosis, and we were able to observe

enormous swellings on seriously burnt persons immersed in hypotonic solutions (water), putting into danger the life of the injured.
When they get into contact with the tissues, strong bases show the potentialities of the OH^- ion, which can, by proteic catalysis, penetrate quickly into the tissues, opposite to H^+ ion, which coagulates the tissues, then slowing down its own penetration.
Whatever the quantity of base splashed on the face, the quantities that arrive on the eye are reduced taking into account on one hand the small surface of the eye and on the other hand the movement of the eyelids which sweeps away the surplus liquid, and we can estimate its volume at around 0,2ml.

III – DECONTAMINATION METHODS

Here we will only consider the first intention decontamination means which can be found on the place of the accident, or reachable within the 2 first minutes. Indeed, the action of bases is extremely quick, and after 5 minutes their penetration in the eye is finished and the lesions are installed.

Two main methods are currently used :

- Rinsing with large amounts of water, which is based on dilution and sweeping effect
- Rinsing with solutions isotonic to the tears, and with buffered and isotonic solutions

The dilution with water aims at decreasing the OH^- ions effect proportional to their concentration.
To decrease the pH of 0,2ml of 1N caustic soda from 14 to 7, you need theoretically 1000 l of water. Luckily, the mechanical washing effects reduce these volumes to lower quantities, but this explains the slow action of water. The main default from water is its hypotonicity ; indeed it penetrates by osmotic pressure into the stroma, taking inside some soda particles which provokes an oedema and lesions to the endothelial cells.
The dilution with solutions isotonic to tears has the advantage to regulate the osmotic pressures, stopping further penetration of the OH^- ion inside the eye.
The neutralisation by buffer solutions :
Buffer solutions are amphoteric agents with acid and basic characteristics and a pH very close to neutrality (between 6,5 and 7,5). These solutions are very interesting for the neutralisation and the necessary quantities are very small as in the above mentioned case of 1N caustic soda, you need $1cm^3$ of anti base solution to reach a pH 7 ; furthermore, it is possible to make these solutions isotonic which combines both advantages.
It is useful to underline that the neutralisation with an amphoteric buffered solution gives a very small heat emission, quite not measurable (around 0,5°C in case of the neutralisation of $1cm^3$ of 10N caustic soda with an anti soda solution necessary to bring the pH back to 7).

IV – MATERIAL AND METHODS

We realised a range of studies on the lesions provoked by caustic soda on the eye, according to different ocular rinsing methods.
In these researches we were specially interested in the first 24 hours which are known to condition the functional prognosis in the long term.
We used 55 albino rabbits, divided in 4 series :

- the first and the second series of 13 rabbits each were devoted to the study of histological lesions
- the third and the fourth series were devoted in the same time to the histological study, but also to the measure of the extra and intra ocular (in the anterior chamber) pH.

The ocular burn was obtained in the three last series with 1 cm diameter paper soaked in 1N caustic soda and drained, then applied during 30 seconds on the animal eye anaesthethized with ether, and after the corneal reflex has disappeared.
Immediately after the paper with the caustic agent has been removed, the eye was rinsed either with tap water thanks to a special shower, or with two solutions, one isotonic to tears (Eyewash, sic-Prevor rinsing solution), and the other one is isotonic and buffered, called anti soda solution (Lav'œil, sic-Prevor anti soda solution).
In the third series the pH of the tears was regularly measured until the end.
In the last series, the measure of the extra ocular pH, and the intra ocular pH measured by puncture of the anterior chamber were made at the end. The animals were sacrificed after a time going from 3 minutes to 24 hours after the ocular burn.
Concerning this protocol, we can remark that the retained times constitute an approximation of the time necessary for an injured person to have access alone or not to the closest first aid point.

V- RESULTS

1 - pH measures

The pH measures were realised thanks to Merck reactive strips, which allow a measure with 0,2 units.
The extra ocular pH is directly measured by application of the strip in the inferior conjunctival cul-de-sac, the pH of the aqueous humour is measured by puncture in the anterior chamber when the animal is sacrificed. The measure is made only once for each eye, as the repeated sampling of the liquid in the anterior chamber would have sensible consequences on the OH^- ion concentration, and as a consequence on the pH of the anterior chamber.
With this puncture, we had a sufficient quantity of liquid to make several measures with the reactive strips presenting several indicators with various colours that permit a very reliable reading of the results.

A – Extra ocular pH measure (Tableau I, original paper in French)

The measures gathered in tableau I show that the return to a normal pH is very slow with water, much quicker with the isotonic solution, and quite immediate with the buffered isotonic solution.
The theoretical calculations show that the return to a normal pH with the buffered solution can be reached in 1 second, our studies show that after 10 seconds, this result is reached. (tableau I)

B – Intra ocular pH measure

The table gathering the results obtained show that 3 minutes after the burn the pH is equal to 8 with the isotonic solutions and 8,7 with water. Then the pH decreases to reach an area of

normal pH in 30 seconds with the isotonic solutions and in 4 hours with water. The buffered isotonic solution shows a lower increase and a quicker and more important decrease with a slight increase characteristic from an automatism curve (Tableau II, original paper in French).
It is interesting to consider also the figures of the beginning which permit to explain the histological lesions described below. By using water, the pH goes to very high zones, responsible for the destruction of the endothelial cells. Even if the rinsing with water was carried on during a very prolonged time, this precocious increase conditions the final prognosis.

2- Histology

Caustic soda, at 1N concentration that is used always destroys the surface epithelium and whatever the treatment used, it is not possible to preserve it as it is destroyed quite immediately when the caustic is applied.
All series show then an epithelial ulceration from the first minutes.
The stroma underlying to the epithelium, separated from it by the Bowman membrane presents an oedema that varies according to the solution employed : it is a major one for water, visible for the solutions and buffered and isotonic solutions, but less important.
This oedema is responsible for the loss of transparency of the cornea.
And this oedema is due, of course, to the penetration of liquid inside the cornea, but especially to the alteration of the function of the endothelial cells, which, located in the posterior part of the stroma are used to pump the liquids in presence.
The stroma presents in its anterior part a modification of its tinctorial properties in relation with chemical and physical modifications which look very much like the coagulation lesions as they are observed in thermal lesions and this mechanism seems possible to us, taking into account that the contact of soda with the eye provokes a heat release, as in all irreversible chemical reactions.
The preliminary studies we did show that in the case of a rinsing with water, there is a complete destruction of the endothelial cells, and we sometimes see parts of them floating in the anterior chamber.
When the eye is rinsed with a solution isotonic to the tears, the endothelial cells persist partly, and present cytoplasmic inflation lesions that correspond to the oedema but their number is still quite important.
And finally when the buffered isotonic solution is used, the endothelial cells present a few morphologic variations, but their number is only slightly diminished.
This important number plays a very important role in the recuperation of the functional capacities of the cornea and the studies we carried out seem to show in addition a quicker regrowth of the corneal epithelium, which can be explained, according to us by the reestablishment of a normal corneal function favouring the epithelial regrowth.

DISCUSSION

It can seem surprising first to question the dogma of ocular rinsing with water, but the physico chemical evidences already spoke in favour of the use of buffered and isotonic to tears solutions. The results we bring completely confirm this point of view, and it is useful to remind that different authors showed that the use of isotonic solutions was reducing the lesions of endothelial cells and showed a better cellular regeneration In the works that have been done, isotonic solutions were used either by external application or by rinsing of the anterior chamber. (Benett, Korey)
The authors also showed that it was important to intervene in the first half hour after the burn.

Our results incite us to think, what is obvious, that it is necessary to intervene as early as possible and especially in the very first minutes.
The pH measures show that around half an hour is necessary for the pH to go back to a value close to the normal one with isotonic solutions when 4 hours are necessary to obtain the same result with water.
This result can be explained in the same time by the increased penetration of soda in the eye, favoured by the fluid movement to the inside of the eye, and also by the small neutralisation capacities of water that demand enormous quantities of water compared to isotonic solutions, buffered or not.

CONCLUSION

The studies carried out in the first minutes and the first hours following an ocular burn due to caustic soda show that the use of isotonic solutions and especially buffered isotonic solutions re establishes more quickly the extra and also intra ocular pH, and preserves a large quantity of endothelial cells which are destroyed when the eye is rinsed with tap water.
It appears then as sure that the use of buffered isotonic solutions gives a better chance to keep a correct ocular function in case of ocular accidents due to burns.

BIBLIOGRAPHY

See the original paper in French